NBS REPORT

6058

FABRICATION TECHNIQUES FOR TWO TYPES OF CERAMIC X-BAND RESONANT CAVITIES

by

Frank E. Freethey, Moody C. Thompson, Jr. and Donald M. Waters

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
BOULDER LABORATORIES
Boulder, Colorado

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 8390-11-8305

May 22, 1959

NBS REPORT 6058

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Introduction

Having determined the excellent thermal stability ($< .1$ N/C$^{\circ}$) of McDanel L53A ceramic by tests of a closed resonant microwave cavity constructed of this material [1/], it was decided that a useful extension of this work would be an attempt to fabricate a sampling cavity of the same ceramic for use with a microwave refractometer. The following text outlines in some detail the steps involved in this experiment, including (1) procurement of the material, fabrication procedure, tuning techniques, and evaluation of the completed cavity; (2) the construction of a reference or closed cavity of L53A in which no metallic or other screws are used to attach the end plate or waveguide flanges; (3) a description of tentative holding devices to be used to install the cavity in the refractometer circuit; and (4) a description of an alternative method of tuning a sampling and a reference cavity to matched resonance during the process of fabrication.

Fabrication of a Ceramic Sampling Cavity

The dimensions of the proposed cavity were chosen to correspond to those of a prototype metallic cavity having an I. D. of 1.635", length of 2.360", and parallel end surfaces consisting of rings 1.010" in inside diameter, 1/16" thick, and $\sim$ .45" long, supported by four 1/16" wide

struts attached to the ends of the cavity barrel. In this way it was hoped to obtain a resonant frequency of about 9380 mcs with more than 92% of the parallel ends of the cavity open to the flow of air.

The L53A ceramic for this purpose was obtained from the McDanel Refractory Porcelain Company of Beaver Falls, Pennsylvania, in the following forms:

		Dimensions	
Right cylindrical tubes (to form barrel of cavity)	I. D.	1.635"	± .002"
	O. D.	2.500"	± .0625"
	Length	2.359"	± .002"
Right cylindrical tubes (from which to cut off central rings for sampling cavity ends)	I. D.	1.010"	± .002"
	O. D.	1.150"	± .002"
	Length ~	4.0"	
Flat strips (from which to cut supporting struts for central rings)	Width	0.375"	± .003"
	Thickness ~	0.060"	
	Length ~	12.0"	

The flat strips were cut into .75" lengths to be used as support struts extending from slots in the wall of the cavity barrel to the central rings forming the cavity ends. The central rings consisted of pieces cut from the smaller of the cylindrical ceramic tubes at right angles to the axis of the tube and approximately .450" long.

The choice of form and dimensions for those pieces from which the cavity barrel would be made was determined by the desire to reduce the number of grinding operations necessary, and to obviate the attachment of end plates and waveguide flanges with screws. An arbor (Fig. 1) was made of hardened steel, consisting of a cylindrical rod just large enough to slip closely through the cavity barrel. The barrel was held

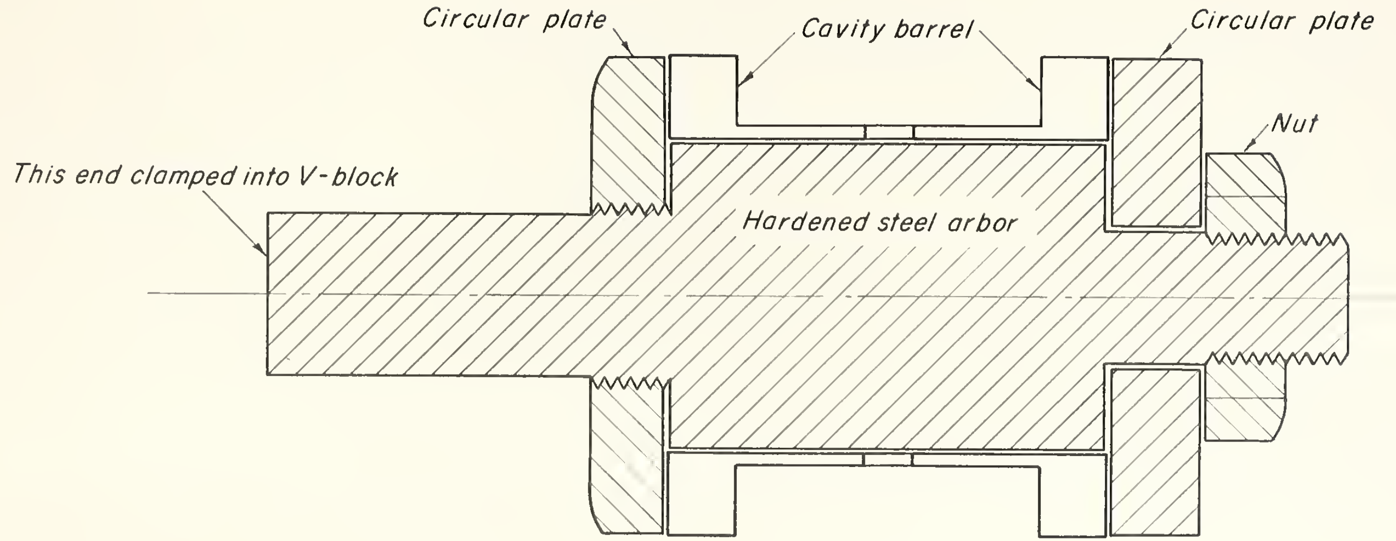

FIG. I ARBOR FOR HOLDING CERAMIC SAMPLING CAVITY BARREL DURING GRINDING

firmly in place on this rod by two steel end plates of approximately the same outside diameter as the barrel itself. Cylindrical extensions from each end of the rod, coaxial with it, were appropriately threaded to permit the end plates to be drawn tight against the ceramic cylinder ends, and one of these extensions, about an inch in diameter, was made long enough to be clamped firmly in a V-block which provided the means for holding the work in place on the magnetic table of the grinding wheel and insured its accurate positioning for the grinding of the parallel flats on opposite sides of the barrel. The parallelism of the flats having been established by shallow preliminary grinding until they were about an inch in width, circular coupling orifices .25" in diameter were bored through the center of each, midway between the cylinder ends. The parallel flats were then ground down until the edges of the orifices, at their thinnest points, were .060" thick. To keep the barrel as strong as possible, the axial length of the flats was made only 1.635", leaving rings of material of the same circumference as the original barrel and about .362" wide around each end. Slots approximately .355" deep and .061" wide were then sawed radially at 90° intervals around the circumference into each end of the cylinder barrel with a diamond wheel to accommodate the struts which were to support the central rings. This completed the machining process.

Three coats of Dupont #6296 silver paste, applied with a brush, were next fired onto the barrel separately at 1385° F. This firing cycle consists in raising the furnace temperature from ambient to 1385° F., holding it there for a "soaking" period of three or four minutes, and shutting off the furnace to allow the cavity to cool slowly until it returns

to room temperature. The same number of coats were similarly fired onto the two end rings and their eight supporting struts prior to any attempts to assemble the cavity elements. Since the rings would extend slightly (about 3/32") beyond the ends of the barrel, a flat plate of ceramic was counterground to such a depth that the rings, when resting in this recess as the barrel end sat on the unground surface of the plate, would have their inner surfaces separated by the desired distance. Since no more specific a resonant frequency than "approximately 9400 mcs" was desired, this separation was not a critical one, although an attempt was made to duplicate the metallic prototype in which the end rings' inner surfaces were 1.65" apart, and which had resonated at 9381 mcs. Using the plate in this manner as a rest, each ring with its struts was fired on separately using heavy coats of Dupont paint #6296 to coat all adjoining surfaces, viz., the junctions of the struts with the ring, and the interior surfaces of the slots in the barrel into which the struts were seated. The assembled sampling cavity is shown in Figs. 2a and 2b.

In order to avoid the use of screws and tapped inserts cemented into the cavity barrel for attachment of waveguide flanges, and to facilitate the mounting of the cavity into the circuit without subjecting it to strains that might lead to early fracture of the barrel itself, a split brass collar was devised to hold the waveguide flanges, using choke and "O" ring junctions, firmly over the coupling orifices and against the parallel flats. (See Figs. 3a and 3b) The cavity is easily installed into one half of the collar before the other half is joined to it and tightened about the barrel. It is felt that significant improvements in design can be made over this tentative arrangement, both to reduce its size and weight, and to protect it from the severe shock or vibration to which its use in airplanes might subject it.

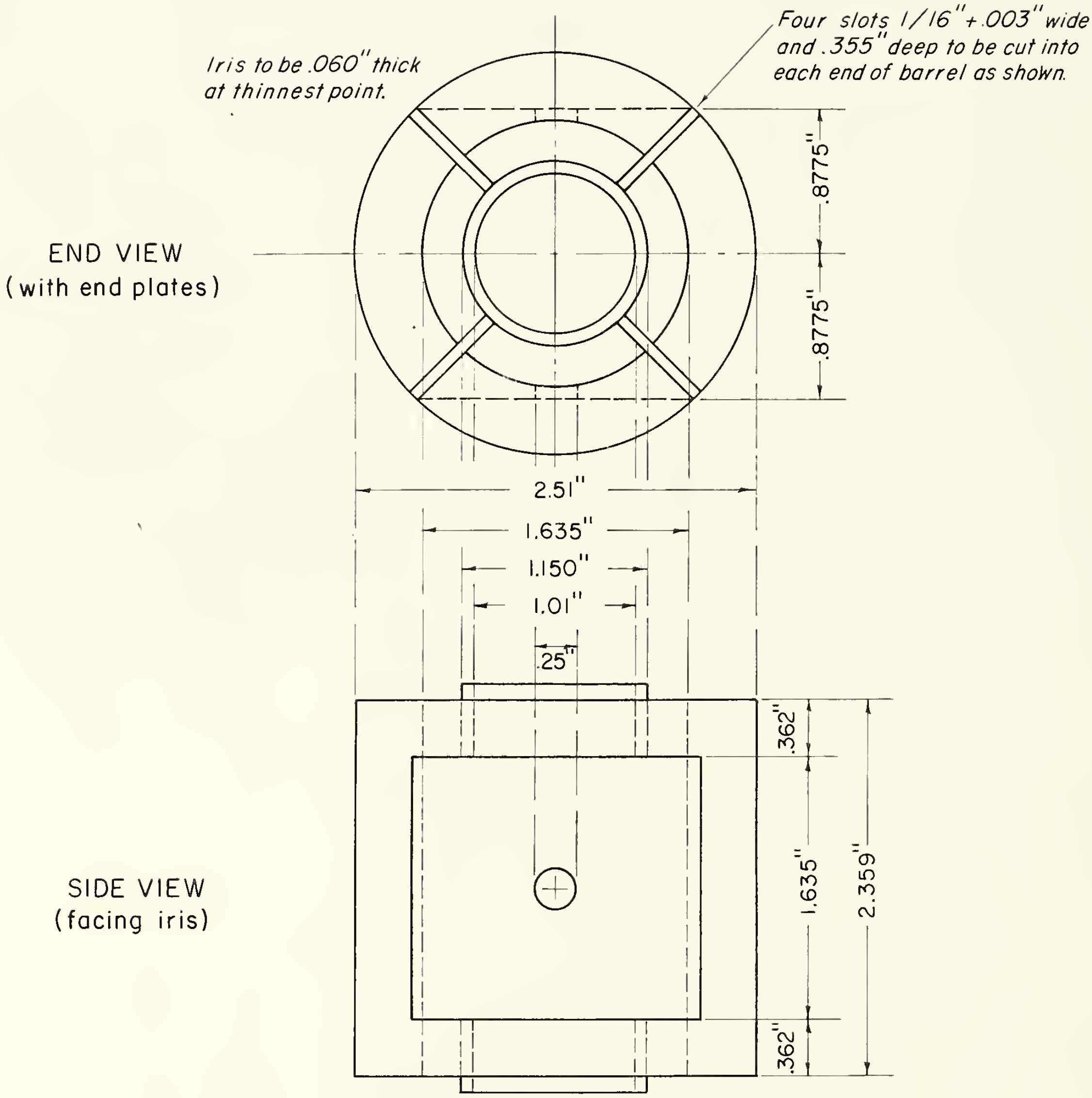

FIG. 2a CERAMIC SAMPLING CAVITY

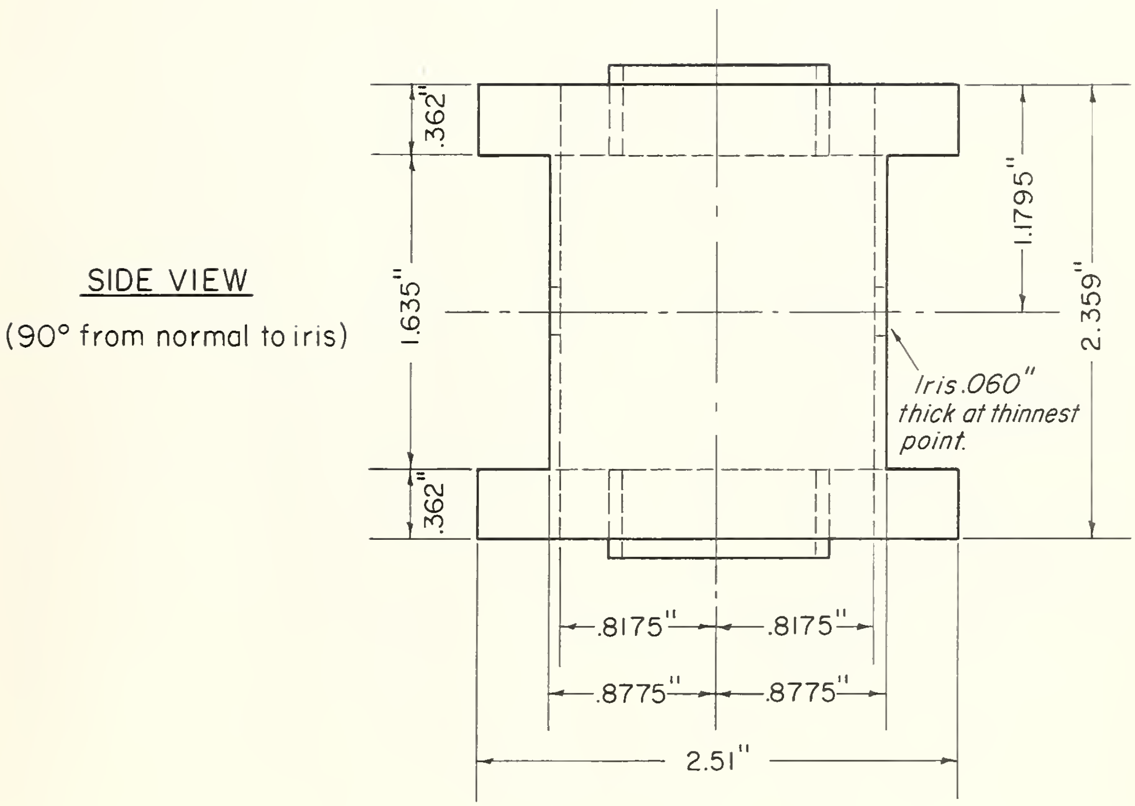
SIDE VIEW
(90° from normal to iris)
.362"
1.635"
.362"
1.1795"
2.359"
Iris .060" thick at thinnest point.
.8175"
.8175"
.8775"
.8775"
2.51"

Figure 2b

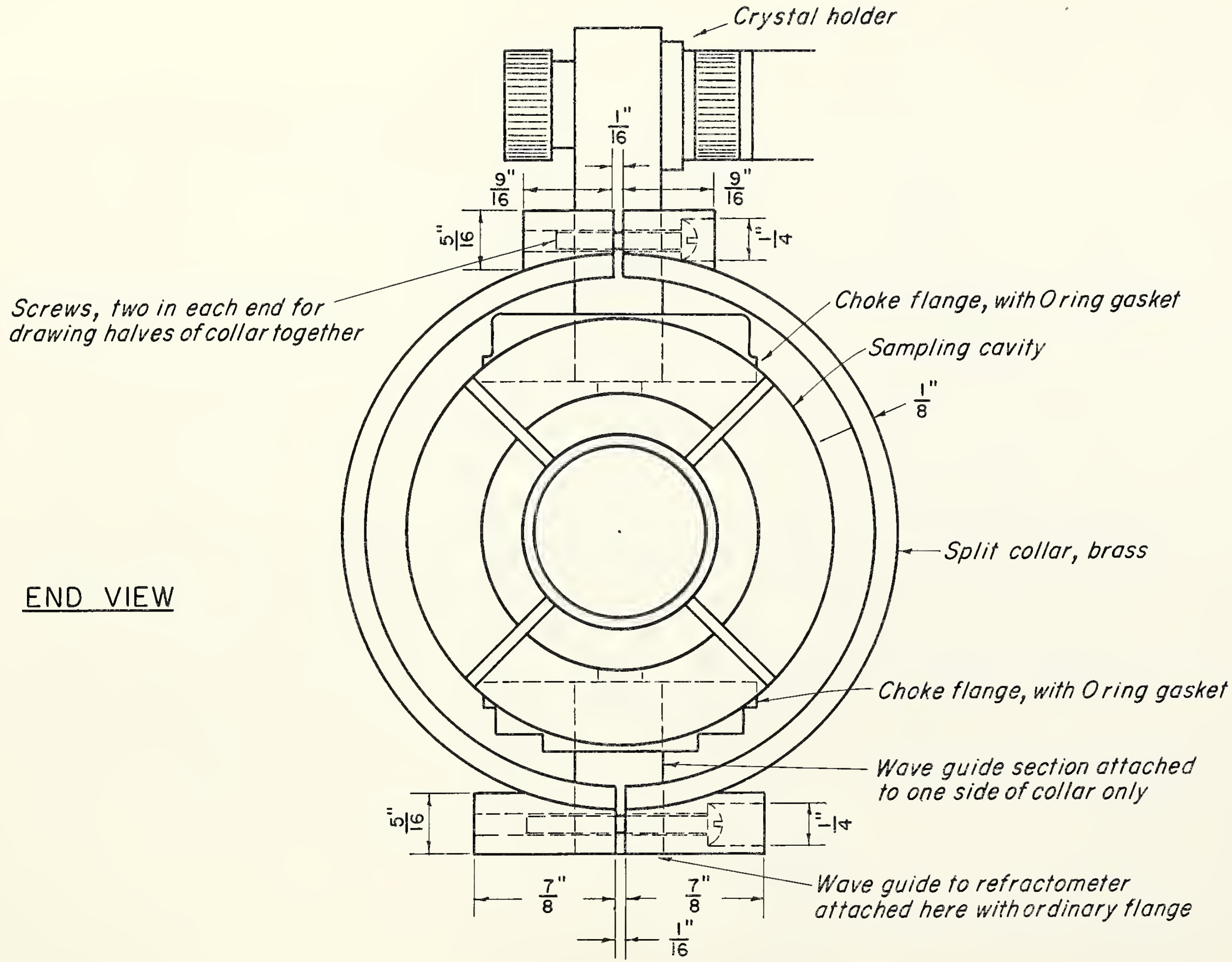

FIG. 3a TENTATIVE DESIGN FOR HOLDER FOR CERAMIC SAMPLING CAVITY

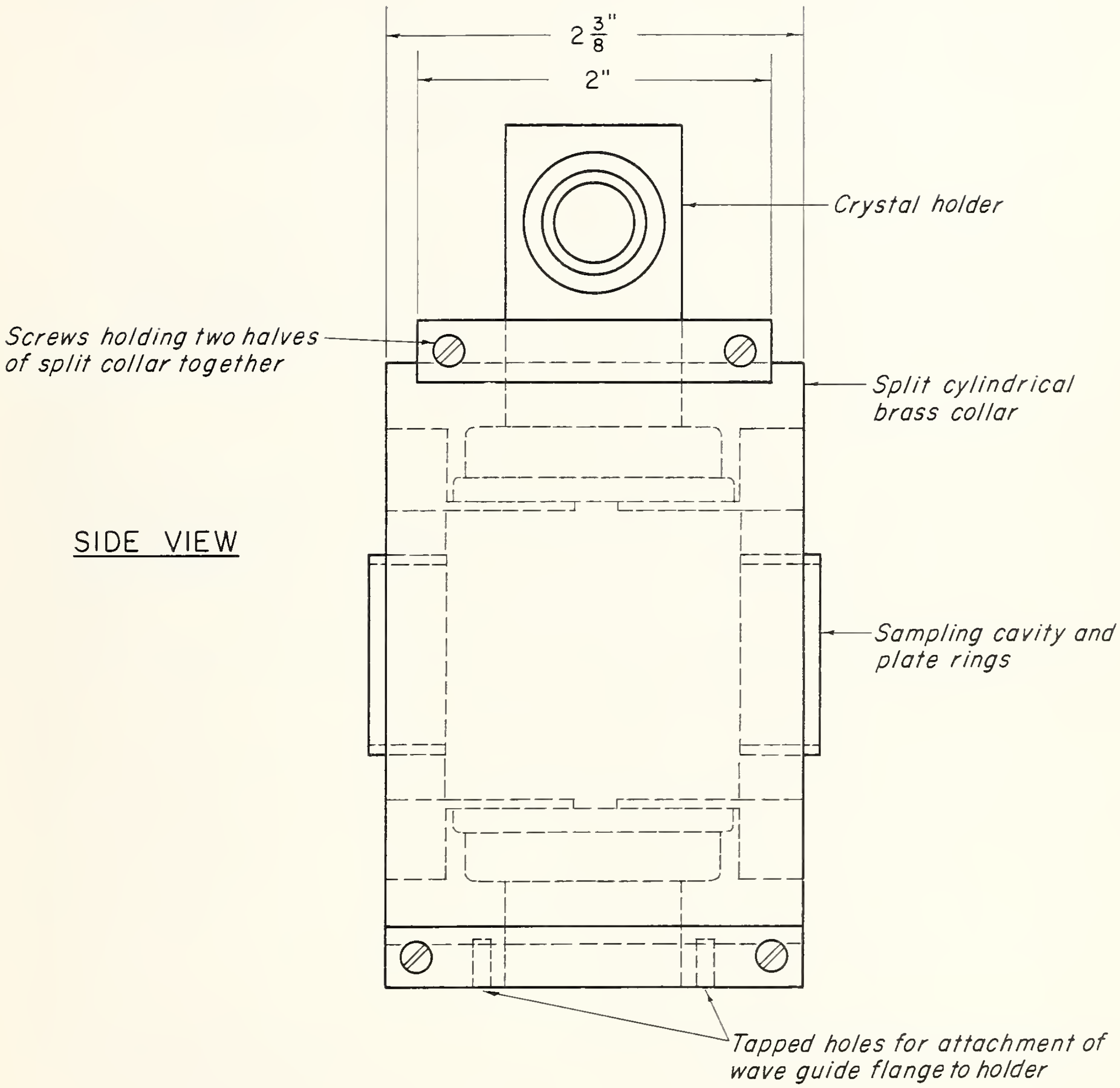
2 3/8"
2"
Crystal holder
Screws holding two halves of split collar together
Split cylindrical brass collar
SIDE VIEW
Sampling cavity and plate rings
Tapped holes for attachment of wave guide flange to holder

Figure 3b

The completed cavity, mounted in this holder and installed in a refractometer, proved upon measurement to have a resonant frequency of 9383 mcs (only 2 mcs higher than its metallic prototype) and a Q of about 7700.

Fabrication of a Ceramic Reference Cavity To Match a Fixed Frequency Sampling Cavity

To make a closed ceramic reference cavity, matched in frequency to the ceramic sampling cavity described above, the interior of a cup of L53A, about 2.75" in outside diameter, 1.954" inside diameter, and 1.055"deep, was first ground to true right cylindrical form which changed the inside diameter to 1.957" and the depth to 1.058". Parallel flats were next ground on opposite sides of the cup and circular coupling orifices .25" in diameter drilled through the center of these flats, each flat being cut to such a depth as to make the thinnest part of the orifice edge .060" in thickness. The single end plate of the cavity, a circular disk of L53A about 13/32" thick was ground off on opposite edges to match the end of the cup in shape. (See Fig. 4)

Three coats of Dupont silver paste #6296 were next separately fired on both the barrel and the end plate, and it was found upon measurement to be resonant at 9212 mcs and to have a Q of 8600. To match it frequency-wise to the ceramic sampling cavity already constructed, which resonated at 9383 mcs, the length was shortened by grinding off the rim around the open end of the cup. This was done in small decrements. Beginning with cuts of .002" to .003" and making frequency determinations after each cut was made, the length was reduced to approximately 1.046". A series of cuts of .001" each was begun at this point and continued until the length was only about 1.042". Finally, cuts of only .0005" were

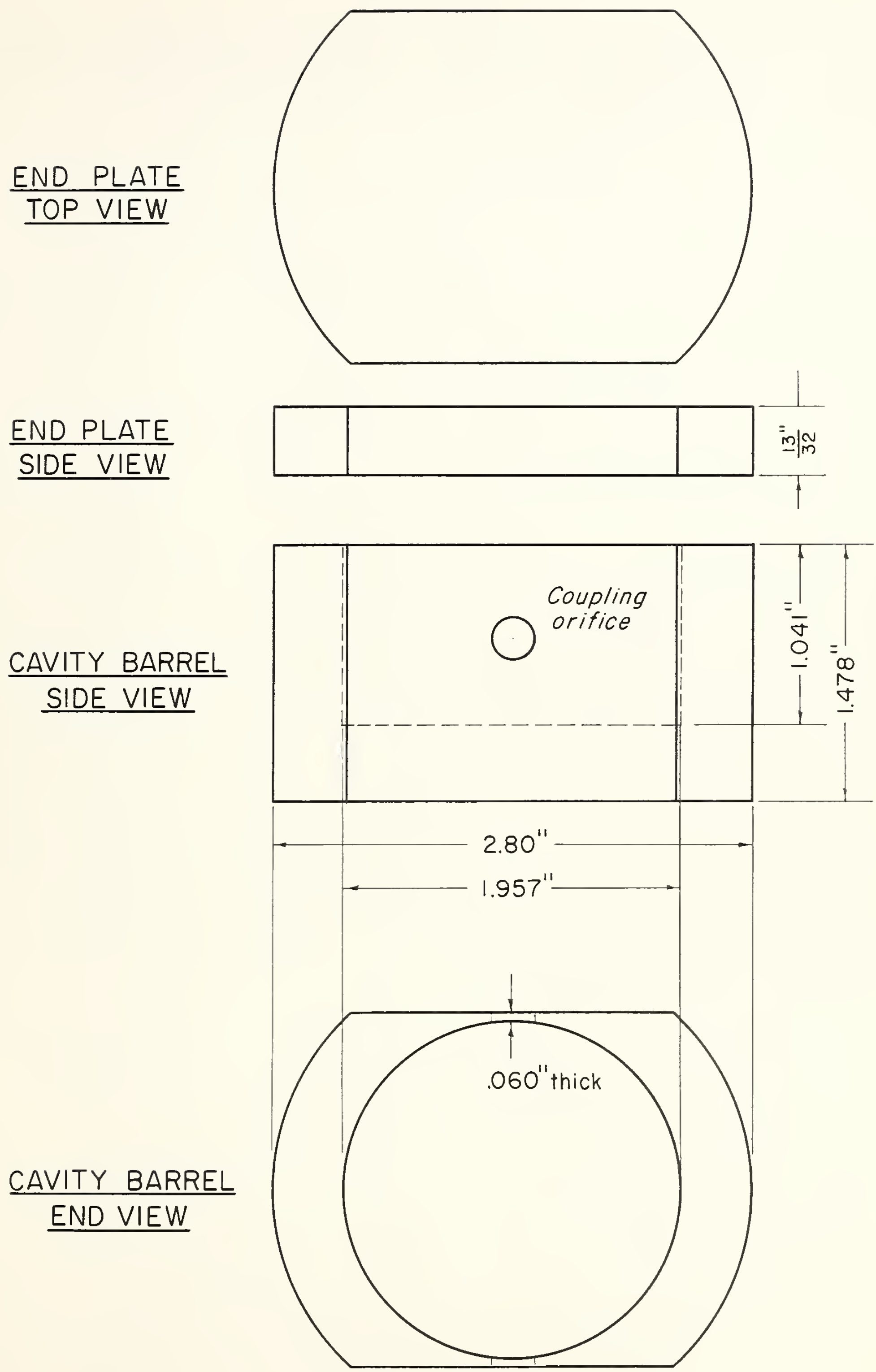

FIG. 4 SKETCH OF CERAMIC REFERENCE CAVITY

used as the frequency approached more and more closely the desired value of 9383 mcs. Upon finally achieving this frequency for the reference cavity, a rather thick coat of Dupont #6296 paint was applied to the rim of the cup and the end plate was fired on, using the paint as a soldering medium. To offset the expected drop in frequency resulting from a lengthening of the barrel due to the layer of paint between the end plate and the rim, a heavy coat of paint was applied to the bottom of the cup before the firing was done. This proved to be a mistake, for the cavity after firing, was found to have gone up in frequency by about 3 mcs, denoting a shortening of the barrel in the last operation. It is believed that the extra paint in the cavity's bottom, being atop layers already there, decreased the cavity length, while that between the end plate and the rim was largely absorbed by the unpainted ceramic rim and, hence, did not provide the expected compensating increase in length. Since no provision for tuning was incorporated into these cavities, and the difference in their respective resonant frequencies for optimum use as reference and sampling cavities in the refractometer must be no more than 1.5 mcs, it is important that this last operation be done with care. It is believed that no compensating painting of the bottom of the cavity is necessary prior to "soldering" on the end plate.

This cavity also was designed to eliminate the use of all screws in contact with the ceramic body, either for attaching the waveguide flanges to the parallel flats or the end plate to the cavity barrel. A holder similar in general design to that used with the sampling cavity described above was made for inserting the reference cavity into the refractometer circuit for test. Since it is now contemplated that the reference cavity can most conveniently be sealed by devising a hermetic chamber of some sort to contain it, the details of the holder presently in use are omitted.

Alternative Method for Matching Fixed Frequency Ceramic Cavities During Process of Fabrication

The tuning of "matched pairs" of these cavities (a sampling and a reference type) is perhaps most easily done by first fabricating the reference cavity and tuning the sampling cavity to match its resonant frequency.

The procedure for tuning the sampling cavity is as follows:

1. Assemble and "solder" together with the silver paint all components of the cavity except the ring element in one of the open ends.
2. So position the struts radially in this end <u>before firing</u> that when the ring is slipped into the nest formed by their inner ends it will be properly located axially (concentric with the cylinder axis) and have sufficient clearance from the struts to allow it to move freely along the cylinder axis.
3. Place the reference cavity to be matched in the refractometer with the sampling cavity to be tuned and while monitoring the two frequencies simultaneously on the oscilloscope, move the ring within the nest formed by the strut ends until the patterns indicate the frequency match desired. Carefully deposit several drops of silver paint at each strut junction with the ring, allow to air dry for an hour, remove the cavity from the refractometer, and using great care not to disturb the ring position in any way, place it in the electric oven and fire the ring rigidly in place.

4. After this firing, apply paint liberally to the four strut-ring junctions and fire again to finish the job. No significant displacement of the ring will occur in these firings if the cavity is placed in the oven so that the weight of the ring is sustained by the ends of the struts, and not by the uncured paint alone.

Summary

Both closed reference cavities and widely opened sampling cavities in frequency matched pairs for microwave refractometers may be constructed of a very low thermal coefficient ceramic body, McDanel type L53A, with a minimum of machining and at considerable saving in fabrication cost by the technique described above. Because of the extraordinary thermal stability ($< .1\ N/C^{o}$) of the material itself, extra temperature compensating devices are unnecessary. If a tuning element is considered advisable, however, no difficulty is foreseen in putting such an element into the sampling cavity wall where gas-tight sealing is not a problem. The tuning plunger might, itself, be made of the same ceramic of which the cavity is constructed, thus, further improving the temperature stability of the frequency at which it is set. Devices for holding the cavities for insertion into the waveguide circuit without the use of metallic screws or any direct metallic connection between the waveguide and the ceramic body are believed to be feasible and simple to construct. Features may be incorporated into these devices, too, that will afford vibration and shock protection to the property of fragility and brittleness which characterize the ceramic.

References

1/ M. C. Thompson, Jr., Frank E. Freethey, and Donald M. Waters, "Fabrication Techniques for Ceramic X-Band Cavity Resonators," Review of Scientific Instruments, Vol. 29, No. 10, Pages 865-868, October 1958.

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